

In August 2007, Arctic sea ice area (recall that “area” is a different metric than “extent” used in the preceding paragraphs) also broke the record for the minimum Arctic sea ice area in the period since the satellite PM record began in the 1970s (University of Illinois Polar Research Group 2007 web site; <http://arctic.atmos.uiuc.edu/cryosphere/>). The new record was set a full month before the historic summer minimum typically occurs, and the record minimum continued to decrease over the next several weeks (University of Illinois Polar Research Group 2007 web site). The Arctic sea ice area reached an historic minimum of 2.92 million sq km (1.13 million sq mi) on September 16, 2007, which was 27 percent lower than the previous (2005) record Arctic ice minimum area (University of Illinois Polar Research Group 2007 web site). In previous record sea ice minimum years, ice area anomalies were confined to certain sectors (North Atlantic, Beaufort/Bering Sea, etc.), but the character of the 2007 summer sea ice melt was unique in that it was both dramatic and covered the entire Arctic Basin. Atlantic, Pacific, and the central Arctic sectors all showed large negative sea ice area anomalies (University of Illinois Polar Research Group 2007 web site).

Two key factors contributed to the September 2007 extreme sea ice minimum: thinning of the pack ice in recent decades and an unusual pattern of atmospheric circulation (Stroeve et al. 2008). Spring 2007 started out with less ice and thinner ice than normal. Ice thickness estimates from the ICESat satellite laser altimeter instrument indicated ice thicknesses over the Arctic Basin in March 2007 of only 1 to 2 m (3.3 to 6.6 ft) (J. Stroeve, in litt. to the Service, November 2007). Thinner ice takes less energy to melt than thicker ice, so the stage was set for low levels of sea ice in summer 2007 (J. Stroeve, quoted in NSIDC Press Release, October 1, 2007). In general, older sea ice is thicker than younger ice. Maslanik et al. (2007) used an ice-tracking computer algorithm to estimate changes in the distribution of multi-year sea ice of various ages. They estimated: that the area of sea ice at least 5 years old decreased by 56 percent between 1985 and 2007; that ice at least 7 years old decreased from 21 percent of the ice cover in 1988 to 5 percent in 2007; and that sea ice at least 9 years old essentially disappeared from the central Arctic Basin. Maslanik et al. (2007) attributed thinning in recent decades to both ocean-atmospheric circulation patterns and warmer temperatures. Loss

of older ice in the late 1980s to mid-1990s was accentuated by the positive phase of the Arctic Oscillation during that period, leading to increased ice export through the Fram Strait (Stroeve et al. 2008). Another significant change since the late 1990s has been the role of the Beaufort Gyre, “the dominant wind and ice drift regime in the central Arctic” (Maslanik et al. 2007). “Since the late 1990s * * * ice typically has not survived the transit through the southern portion of the Beaufort Gyre,” thus not allowing the ice to circulate in its formerly typical clockwise pattern for years while it aged and thickened (Maslanik et al. 2007). Temperature changes in the Arctic are discussed in detail in the section entitled “Air and Sea Temperatures.”

Another factor that contributed to the sea ice loss in the summer of 2007 was an unusual atmospheric pattern, with persistent high atmospheric pressures over the central Arctic Ocean and lower pressures over Siberia (Stroeve et al. 2008). The skies were fairly clear under the high-pressure cell, promoting strong melt. At the same time, the pattern of winds pumped warm air into the region. While the warm winds fostered further melt, they also helped push ice away from the Siberian shore.

Winter Sea Ice

The maximum extent of Arctic winter sea ice cover, as documented with PM satellite data, has been declining at a lower rate than summer sea ice (Parkinson et al. 1999, p. 20,840; Richter-Menge et al. 2006, p. 16), but that rate appears to have accelerated in recent years. Parkinson and Cavalieri (2002, p. 441) reported that winter sea ice cover declined at a rate of 1.8 percent plus or minus 0.6 percent per decade for the period 1979 through 1999. More recently, Richter-Menge et al. (2006, p. 16) reported that March sea ice extent was declining at a rate of 2 percent per decade based on data from 1979–2005. Comiso (2006) calculated a decline of 1.9 plus or minus 0.5 percent per decade for 1979–2006, and J. Stroeve (in litt. to the Service, November 2007) calculated a decline of 2.5 percent per decade, also for 1979–2005.

In 2005 and 2006, winter maximum sea ice extent set record lows for the era of PM satellite monitoring (October 1978 to present). The 2005 record low winter maximum preceded the then-record low summer minimum during the same year, while winter sea ice extent in 2006 was even lower than that of 2005 (Comiso 2006). The winter 2007 Arctic sea ice maximum was the second-lowest in the satellite record,

narrowly missing the March 2006 record (NSIDC Press Release, April 4, 2007). J. Stroeve (in litt. to the Service, November 2007) calculated a rate of decline of 3.0 plus or minus 0.8 percent per decade for 1979–2007.

Cumulative Annual Sea Ice

Parkinson et al. (1999) documented that Arctic sea ice extent for all seasons (i.e., annual sea ice extent) declined at a rate of 2.8 percent per decade for the period November 1978 through December 1996, with considerable regional variation (the greatest absolute declines were documented for the Kara and Barents Sea, followed by the Seas of Okhotsk and Japan, the Arctic Ocean, Greenland Sea, Hudson Bay, and Canadian Archipelago; percentage declines were greatest in the Seas of Okhotsk and Japan, at 20.1 percent per decade, and the Kara and Barents Seas, at 10.5 percent per decade). More recently, Comiso and Nishio (2008) utilized satellite data gathered from late 1978 into 2006, and estimated an annual rate decline of 3.4 percent plus or minus 0.2 percent per decade. They also found regions where higher negative trends were apparent, including the Greenland Sea (8.0 percent per decade), the Kara/Barents Seas (7.2 percent per decade), the Okhotsk Sea (8.7 percent per decade), and Baffin Bay/Labrador Sea (8.6 percent per decade). Comiso et al. (2008) included satellite data from 1979 through early September 2007 in their analyses. They found that the trend of the entire sea ice cover (seasonal and perennial sea ice) has accelerated from a decline of about 3 percent per decade in 1979–1996 to a decline of about 10 percent per decade in the last 10 years. Statistically significant negative trends in Arctic sea ice extent now occur in all calendar months (Serreze et al. 2007, pp. 1,533–1,536).

Sea Ice Thickness

Sea ice thickness is an important element of the Arctic climate system. The sea ice thickness distribution influences the sea ice mass budget and ice/ocean/atmosphere exchange (Holland et al. 2006a). Sea ice thickness has primarily been measured with upward-looking sonar on submarines and on moored buoys; this sonar provides information on ice draft, the component of the total ice thickness (about 90 percent) that projects below the water surface (Serreze et al. 2007, pp. 1,533–1,536). Rothrock et al. (1999, p. 3,469) compared sea-ice draft data acquired on submarine cruises between 1993 and 1997 with similar data acquired between 1958 and 1976, and concluded that the mean sea-ice draft at